Application Note

Hyposaturation type Surface Molding Series Regulator IC

SI-3000LSA Series

August 2011 Rev.1.1

SANKEN ELECTRIC CO., LTD.

――― Contents ―――

1. General Information

The SI-3000LSA is a series regulator IC using a hyposaturation type PNP bipolar transistor in the power section and it can be used with the low difference of input/output voltages. It is provided with an ON / OFF terminal which operates in "Active High" mode and the current consumption of circuits at OFF time is zero. It is a regulator which can use electrolytic capacitors for the output capacitor at the voltage of 16V.

● 1-1 Features

- Output current 1A

  Output current is 1A at maximum with the outline of SOP8.
- Hyposaturation (V_{dif} = 0.8Vmax / Io = 1A, V_{dif} = 0.4Vmax / Io = 0.5A)

  It can be designed with low difference of input/output voltages.
- ON/OFF function

  The ON/OFF terminal which can be directly controlled by TLL logic signals is provided.
- Low current consumption

  Current consumption of circuits at OFF time is zero.
- Built-in Overcurrent protection / Thermal shutdown

  The foldback type overcurrent protection and Thermal shutdown circuits are built-in.
  (Automatic restoration type)

● 1-2 Application

For on-board local power supplies, power supplies for OA equipment, stabilization of secondary output voltage of regulator and power supply for telecommunication equipment

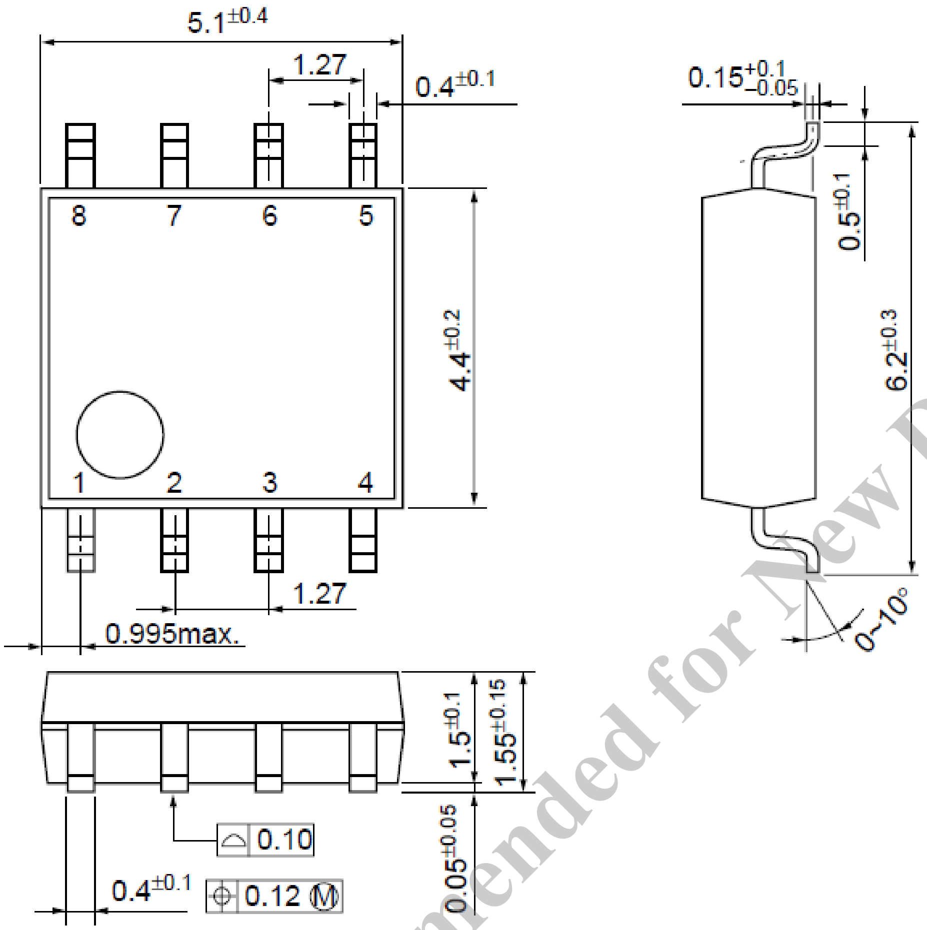
● 1-3 Type

- Type: Semiconductor integrated circuits (monolithic IC)
- Structure: Resin molding type (transfer molding)

2. Specification

Unit: mm

● **2-1 Package Information (Surface Mounting Device: SOP8)**



Pin assignment

1. V_{IN}
2. NC (please use in OPEN state.)
3. V_{IN}
4. V_C
5. GND
6. GND
7. Vo
8. Vo

Resin sealed type

Non-combustibility: UL standards 94V-0

Product mass: about 0.1 g

● 2-2 Ratings

2-2-1 Absolute Maximum Ratings   Ta = 25°C

Parameter	Symbol	Ratings	Unit
DC Input Voltage	V_{IN}	16	V
Output control terminal voltage	V_C	V_{IN}	V
DC Output Current	I_O	1	A
Power Dissipation	P_{D1} *1	1.16	W
	P_{D2} *2	1.1	W
Junction Temperature	T_j *3	–30 to +150	°C
Operating Ambient Temperature	T_{op}	–30 to +150	°C
Storage Temperature	T_{stg}	–30 to +150	°C
Thermal Resistance (Junction to Lead (pin 8))	$\theta_{j\text{-}L}$	36	°C/W
Thermal Resistance (Junction to Ambient Air)	$\theta_{j\text{-}a}$ *2	100	°C/W

*1: When mounted on glass-epoxy board 56.5 × 56.5mm (copper laminate area 100%).

*2: When mounted on glass-epoxy board 40 × 40mm (copper laminate area 100%).

*3: Thermal protection circuits may be activated if the junction temperature exceeds 135°C.

2-2-2 Recommended Operation Conditions

Parameter	Symbol	Ratings				Unit
		SI-3018LSA	SI-3025LSA	SI-3033LSA	SI-3050LSA	
DC Input Voltage Range	V_{IN}	3.1 to 3.5 *1	*2 to 3.5 *1	*2 to 5.2 *1	*2 to 8.0	V
DC Output Current Range	I_O	0 to 1				A
Operating Junction Temperature	T_{jop}	–20 to +125				°C
Operating Ambient Temperature	T_{aop}	–30 to +85				°C

*1: Because of the relation of $P_D = (V_{IN} - V_o) \times I_o$, V_{IN} (max.) and Io (max.) may be restricted subject to conditions of use. For each value, refer to the data of copper foil area - permissible loss for calculation.

*2: It should be Vo + input/output voltage difference.

2-2-3 Electrical Characteristics

Ta = 25°C

Parameter	Symbol	Ratings												Unit
		SI-3018LSA			SI-3025LSA			SI-3033LSA			SI-3050LSA			
		min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	
Output Voltage	V_O	1.764	1.800	1.836	2.450	2.500	2.550	3.234	3.300	3.366	4.90	5.00	5.10	V
	Conditions	V_{IN}=3.3V, I_O=0.5A			V_{IN}=3.3V, I_O=0.5A			V_{IN}=5V, I_O=0.5A			V_{IN}=6V, I_O=0.5A			
Dropout Voltage	V_{DIF}		–				0.4			0.4			0.4	V
	Conditions	–			I_O≤0.5A			I_O≤0.5A			I_O≤0.5A			
			0.6	1.2			0.8			0.8			0.8	
	Conditions	I_O≤1A												
Line Regulation	ΔV_{LINE}		2	10		2	10		3	10		3	15	mV
	Conditions	V_{IN}=3.1 to 3.5V, I_O=0.3A			V_{IN}=3.1 to 3.5V, I_O=0.3A			V_{IN}=4.5 to 5.5V, I_O=0.3A			V_{IN}=6 to 7V, I_O=0.3A			
Load Regulation	ΔV_{OLOAD}		10	20		10	20		10	20		10	30	mV
	Conditions	V_{IN}=3.3V, I_O=0 to 1A			V_{IN}=3.3V, I_O=0 to 1A			V_{IN}=5V, I_O=0 to 1A			V_{IN}=6V, I_O=0 to 1A			
Temperature Coefficient of Output Voltage	$\Delta V_O/\Delta T_a$		±0.3			±0.3			±0.3			±0.5		mV/°C
	Conditions	V_{IN}=3.3V, I_O=5mA, T_j=0 to 100°C			V_{IN}=3.3V, I_O=5mA, T_j=0 to 100°C			V_{IN}=5V, I_O=5mA, T_j=0 to 100°C			V_{IN}=6V, I_O=5mA, T_j=0 to 100°C			
Ripple Rejection	R_{REJ}		60			57			55			55		dB
	Conditions	V_{IN}=3.3V, f=100 to 120Hz			V_{IN}=3.3V, f=100 to 120Hz			V_{IN}=5V, f=100 to 120Hz			V_{IN}=6V, f=100 to 120Hz			
Quiescent Circuit Current	I_q		1.7	2.5		1.7	2.5		1.7	2.5		1.7	2.5	mA
	Conditions	V_{IN}=3.3V, I_O=0A			V_{IN}=3.3V, I_O=0A			V_{IN}=5V, I_O=0A			V_{IN}=6V, I_O=0A			
Circuit Current at Output OFF	I_q(OFF)			1			1			1			1	μA
	Conditions	V_{IN}=3.3V, I_O=0A, V_C=0V			V_{IN}=3.3V, I_O=0A, V_C=0V			V_{IN}=5V, I_O=0A, V_C=0V			V_{IN}=6V, I_O=0A, V_C=0V			
Overcurrent Protection Starting Current*1,3	I_{S1}	1.2			1.2			1.2			1.2			A
	Conditions	V_{IN}=3.3V			V_{IN}=3.3V			V_{IN}=5V			V_{IN}=6V			
Vc Terminal: Control Voltage (Output ON)*2	V_C, IH	2.0			2.0			2.0			2.0			V
Vc Terminal: Control Voltage (Output OFF)*2	V_C, IL			0.8			0.8			0.8			0.8	V
Vc Terminal: Control Current (Output ON)	I_C, IH		40	80		40	80		40	80		40	80	μA
	Conditions	V_C=2V												
Vc Terminal: Control Current (Output OFF)	I_C, IL		0	–5		0	–5		0	–5		0	–5	μA
	Conditions	V_C=0V												

*1: Is1 is specified at the 5% drop point of output voltage Vo on the condition that V_{IN} = 3.3V (5V for SI-3033LSA), and Io = 0.5A.

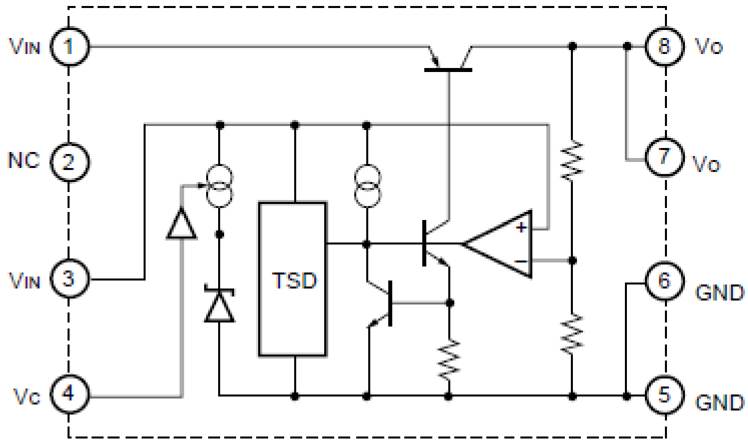
*2: Output is OFF when the output control terminal Vc is open. Each input level is equivalent to LS-TTL level. Therefore, the device can be driven directly by LS-TTLs.

*3: These products cannot be used in the following applications. Because these applications require a certain current at start-up and so the built-in foldback-type over current protection may cause errors during start-up stage.

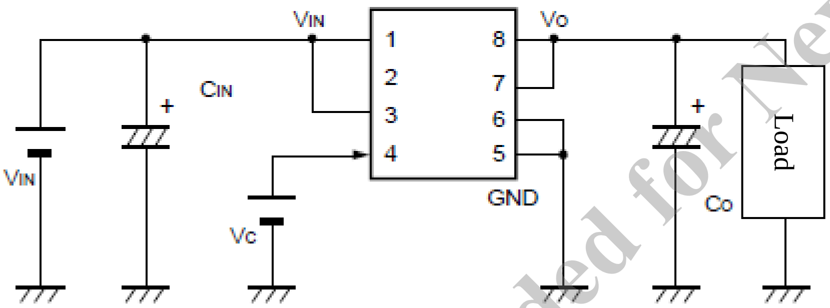
(1) Constant current load (2) Positive and negative power supply (3) Series-connected power supply (4) Vo adjustment by raising ground voltage

● 2-3 Circuit Diagram

2-3-1 Block Diagram



2-3-2 Typical Connection Diagram



Co: Output capacitor (Recommended over 22μF)

C_{IN}: Input capacitor (Recommended around 10μF)

Especially when it is used at low temperature, it is recommended to use tantalum capacitors for C_{IN} and C_O.

*2PIN should be used in OPEN state.

In the case that capacitors having extremely low ESR such as ceramic capacitors are used for output capacitors, they may oscillate. It is recommended to use electrolytic capacitors.

3. Operational Description

● 3-1 Voltage Control

In the SI-3000LSA series, the driving circuit is controlled by comparing the reference voltage with the ADJ terminal voltage (voltage divided by Vo detection resistor in fixed output products) to stabilize the output voltage by varying the voltage between the emitter and collector of a main PNP power transistor. The product of voltage between emitter and collector and the output current at this moment is consumed as heat.

● 3-2 Overcurrent Protection Characteristics

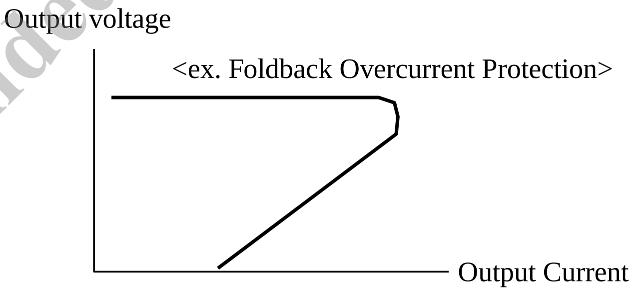
The foldback type overcurrent protection function is provided in the SI-3000LSA series. After operation of the overcurrent protection function, if the load resistance decreases and the output voltage drops, the output current of products is squeezed to reduce the increase of loss. However, in the case of the foldback type overcurrent protection function, since current limiting is also made at start-up, the function may not be used for the following applications, as it may cause a start-up error.

(1) Constant current loads

(2) Plus/minus power supply

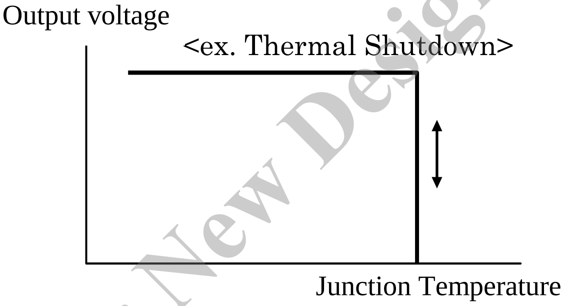
(3) DC power supply

(4) Output voltage adjustment by grounding-up



● 3-3 Thermal Shutdown Characteristics

This IC is provided with the overheat protection circuit which detects the semiconductor junction temperature of the IC to limit the driving current, when the junction temperature exceeds the set value (around 150°C). Since the minimum operating temperature of the overheat protection circuit is 130°C, the thermal design of Tj < 125°C is required. Since the overheat protection has no hysteresis, as soon as the overload state is released and Tj falls below the set temperature, the normal operation is automatically restored. When the overheat protection function is operated in the overload state, the output voltage falls, but at the same time the output current is decreased and in the consequence, overheat protection operation and automatic restoration are repeated in a short interval, resulting eventually in the waveforms of output voltage oscillation.



*Note for thermal shutdown characteristic

This circuit protects the IC against overheat resulting from the instantaneous short circuit, but it should be noted that this function does not assure the operation including reliability in the state that overheat continues due to long time short circuit.

4. Cautions

● 4-1 External Components

4-1-1 Input Capacitor C_{IN}

The input capacitor is required to eliminate noise and stabilize the operation and values of 0.47µF - 22µF are recommended. Any of ceramic capacitors or electrolytic ones may be used for the input capacitor.

4-1-2 Output Capacitor Co

In the output capacitor Co, larger capacitance than the recommended value is required for phase compensation. Equivalent series resistance values (ESR) of capacitors are limited, and depending on products, therefore the type of recommended capacitors is limited.

It is recommended to use electrolytic capacitors. When capacitors with extremely low ESR such as ceramic capacitors, functional polymer capacitors etc., are used, phase margin is decreased, possibly causing the oscillation of output voltage.

4-1-3 Reverse bias protection diode D1

In the case of falling-down of the input voltage, it is recommended to insert a protection diode D1 against the reverse bias between input and output. However, in the case of setting the Vout < 3.3V or lower, D1 is not required including the case of reverse bias. In order to select a suitable D1, it should be taken into consideration that the diode has adequate forward current withstand voltage against the instantaneous discharge of energy stored in Cout.

The permissible value of the forward current per unit time of diode is specified in I_{FSM} (A) and in the case of our diode, it is specified at 50Hz half wave (10ms), but it should be noted that different companies may specify different times. The selection of diode should be made by converting the specified time into the actual discharging time so as to meet the required I_{FSM} (A). The discharging time of Co is normally shorter than 1ms, but it is recommended to do the conversion with 1ms in consideration of margin.

For conversion into I_{FSM}, calculation should be made by using the equations (1) and (2).

$$\left(\frac{I_{FSM}}{\sqrt{2}}\right)^2 * t1 = X \quad \text{--- (1)}$$

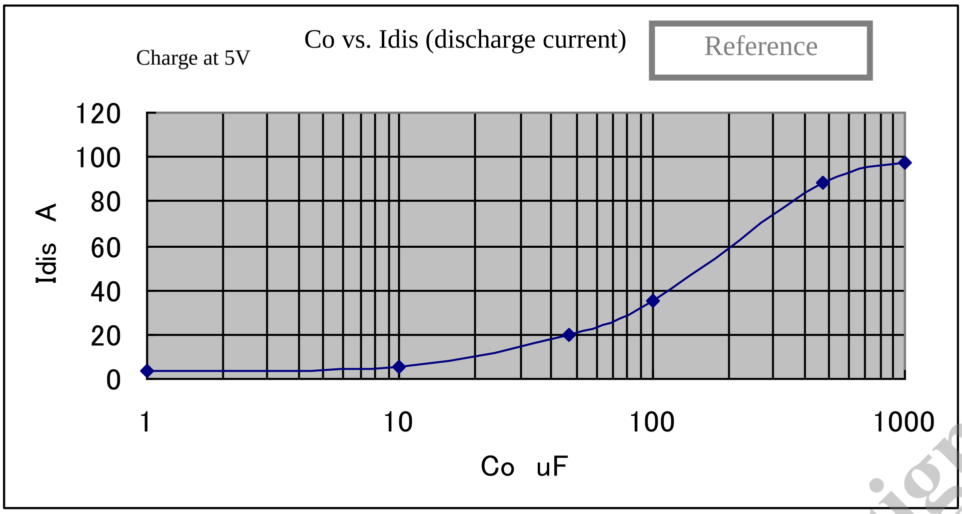
As for I_{FSM}, please refer to the catalog of each company.

t1 = specified time in catalog of each company

$$\text{Converted IFSM} = \sqrt{\frac{2 * X}{t2}} \quad \text{--- (2)}$$

t2: converted time (discharging time of Co)

<Graph 1>



On the assumption of Cout = 470µF, I_{FSM} of around 90A or more (in 1ms time period) is required and according to our specifications of Di, I_{FSM} is specified for 10ms, therefore the Di of 30A has the tolerated dose of 94.8A (in 1ms) to prove that it is usable.

● 4-2 Pattern Design Notes

4-2-1 Input / Output Capacitor

The input capacitor C1 and the output capacitor C2 should be connected to the IC as close as possible. If the rectifying capacitor for AC rectifier circuit is on the input side, it can be used as an input capacitor. However, if it is no close to the IC, the input capacitor should be connected in addition to the rectifying capacitor.

5. Applications

● 5-1 Output ON/OFF Control

The ON/OFF control of output can be made by directly applying voltage to No. 1 Vc terminal. When the Vc terminal is open, the operation is in OFF. The Vc terminal is in OFF below 0.8V and in ON at above 2V.

● 5-2 Thermal Design

Calculation of heat dissipation

Heat generation of the surface mounting IC is generally dependent on size, material and copper foil area of the mounted printed circuit board. Close attention is necessary for the cooling, and you must take margin enough in the "Thermal design". The inner frame stage on which the power devices is mounted is directly connected to the Vout terminals (7, 8 pins). Therefore, the heat dissipation effect is increased by enlarging the copper foil area connected to the Vout terminal.

As the junction temperature Tj (MAX) is an inherent value, it must be observed strictly. For this purpose, heat sink design (thermal resistance of board) which is appropriate for Pd (MAX) and Ta MAX is required. This is graphically shown in the heat derating curve for easy understanding. The heat dissipation design is done in the following procedure.

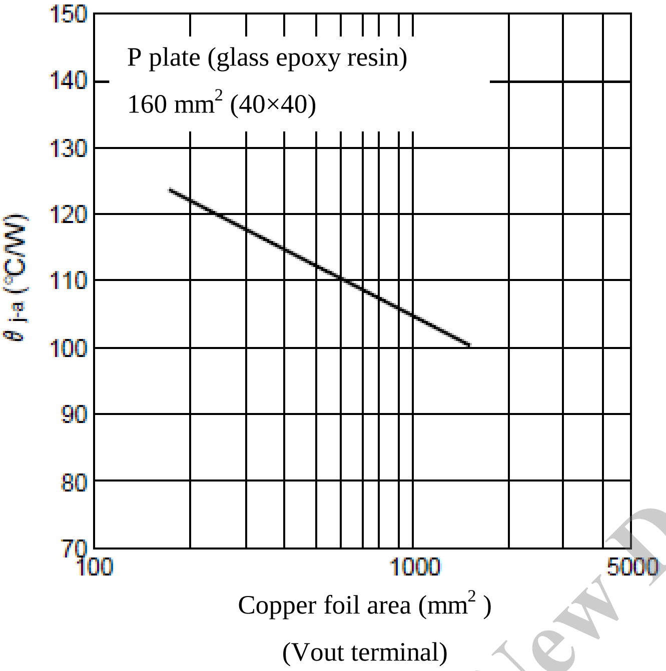
1) The maximum ambient temperature in the set Ta MAX is obtained.

2) The maximum loss PdMAX is obtained by varying input/output conditions to calculate the thermal resistance θj – a.

$$Pd = (VIN - Vout) \times Iout \qquad \theta j\text{-}a = (Tj\text{-}Ta) / Pd$$

3) The area of copper foil is determined from the graph of copper foil area vs. permissible dissipation below shown.

P plate Cu foil area vs junction section – thermal resistance between ambient temperatures



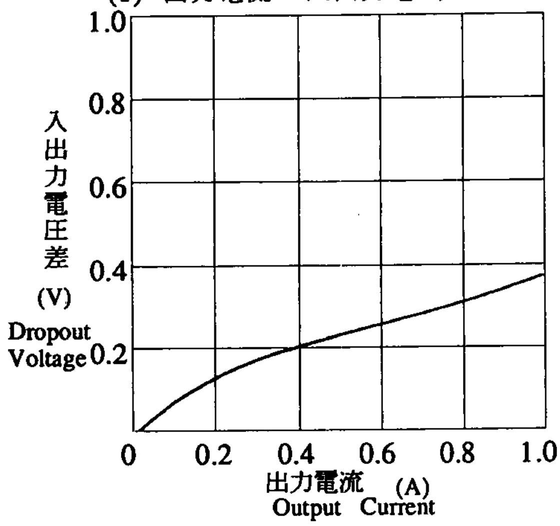
The relation between pattern area and thermal resistance directly connected to No. 7 and 8 pins on the above single side glass epoxy board is shown by the above graph.

6. Typical Characteristics

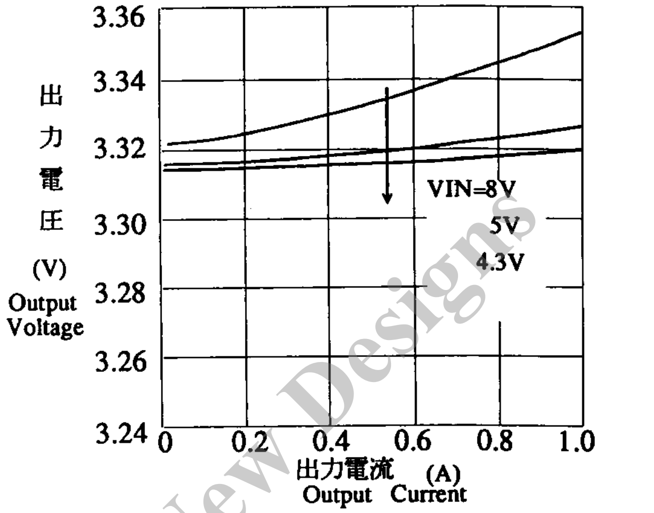
SI-3033LSA 代表特性例(1) (Ta=25℃)

SI-3033LSA Typical Characteristics (1)(Ta=25℃)

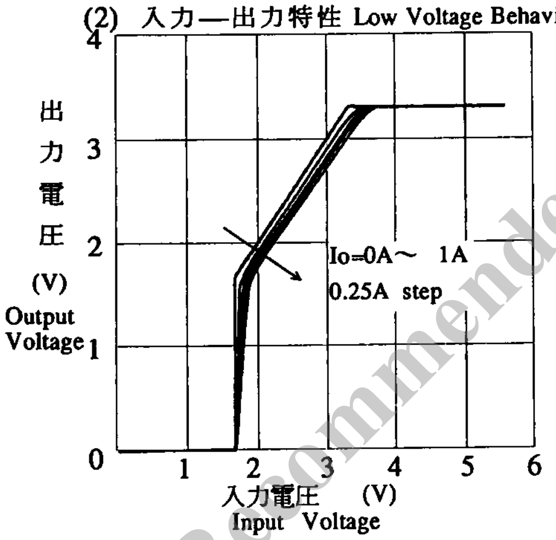
(1) 出力電流—入出力電圧差



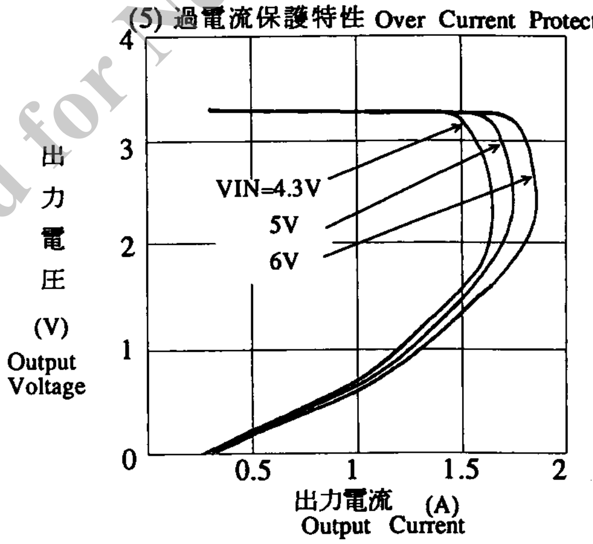
(4) 出力電圧変動(対出力電流) Load Regulation



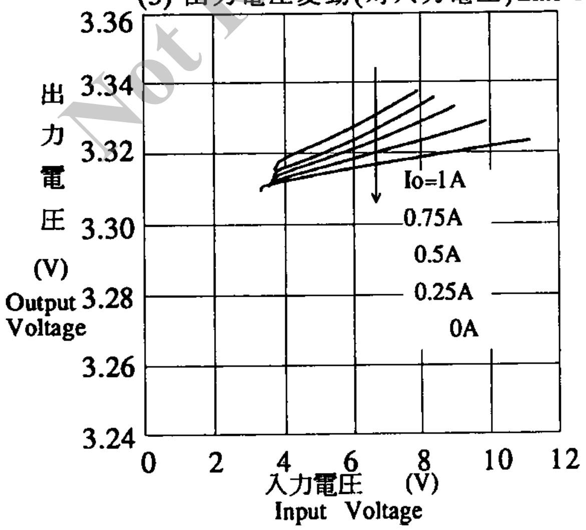
(2) 入力—出力特性 Low Voltage Behavior



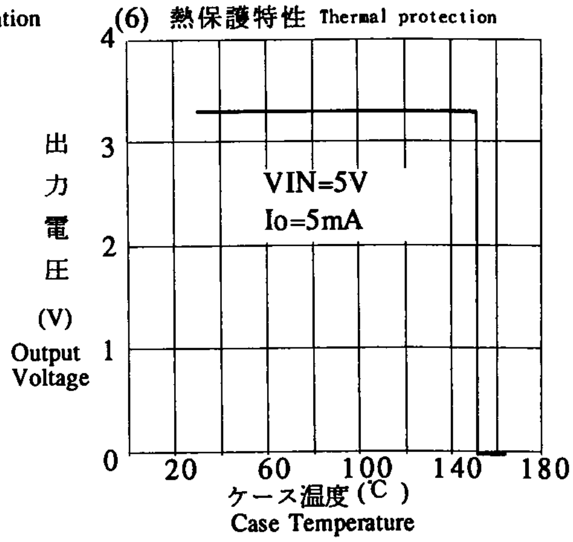
(5) 過電流保護特性 Over Current Protection



(3) 出力電圧変動(対入力電圧) Line Regulation

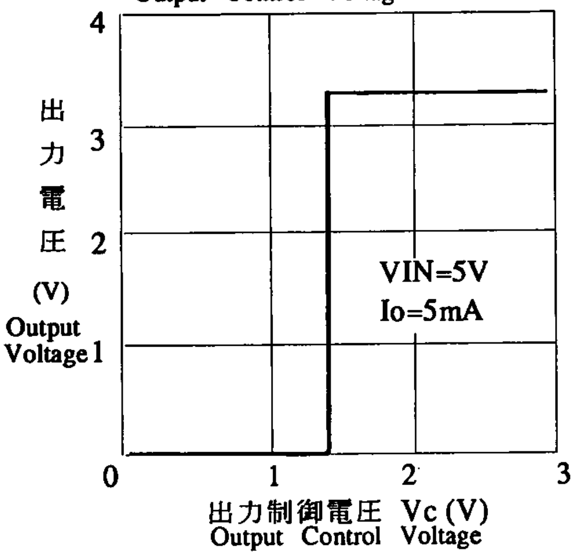


(6) 熱保護特性 Thermal protection

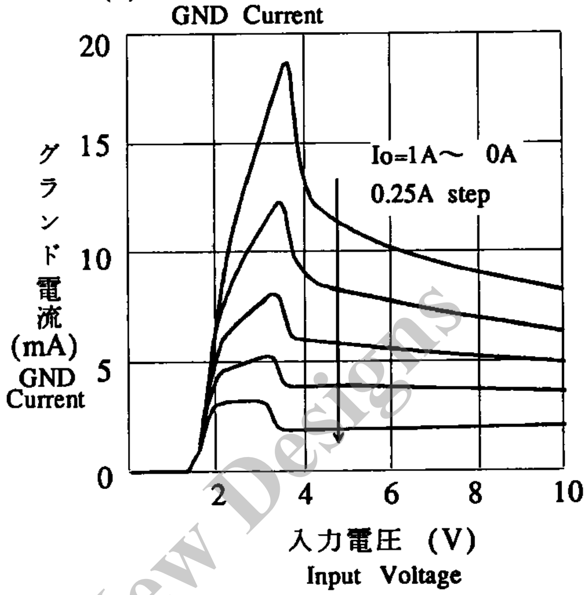


SI-3033LSA 代表特性例(2)（Ta=25℃）
SI-3033I Typical Characteristics (2)(Ta=25℃)

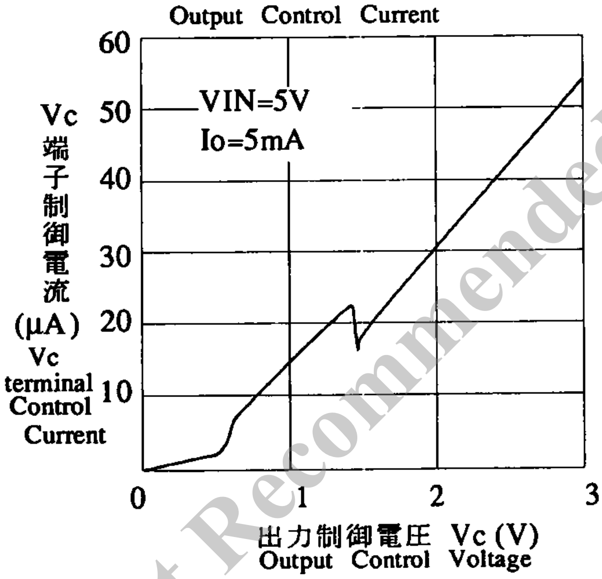
(7) 出力on/off 制御電圧ー出力電圧
Output Control Voltage



(9) 入力—グランド電流
GND Current



(8) 出力on/off 制御電圧ー出力電圧
Output Control Current

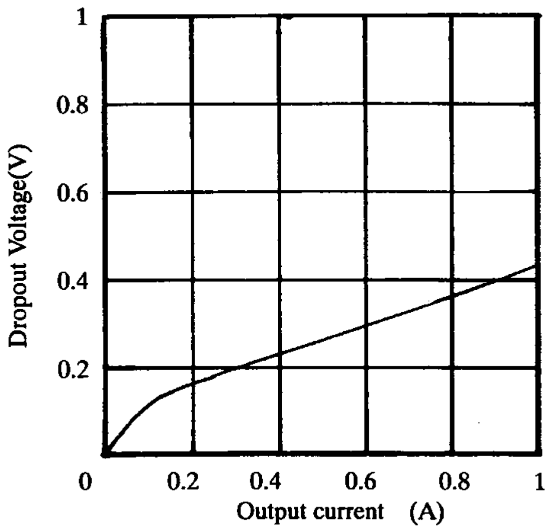


- SI-3050LSA

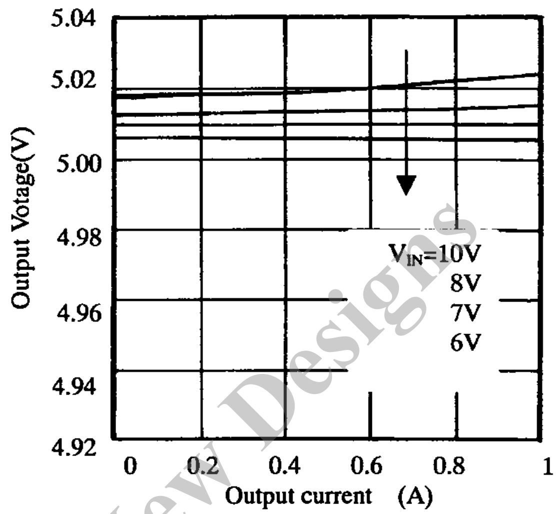
9.SI-3050LS/ 特性例(1) （Ta=25℃）

SI-3050LSA Typical characteristics (1) (Ta=25℃)

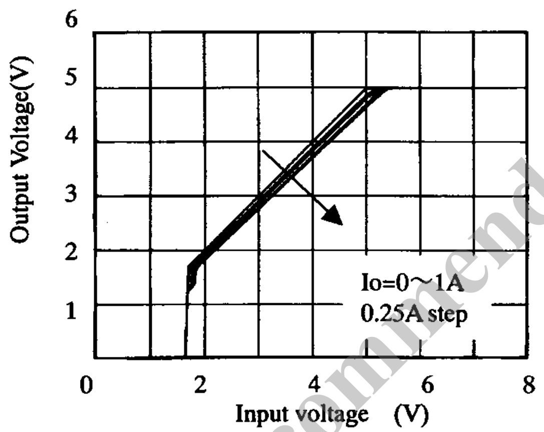
(1) Output current vs. Dropout voltage



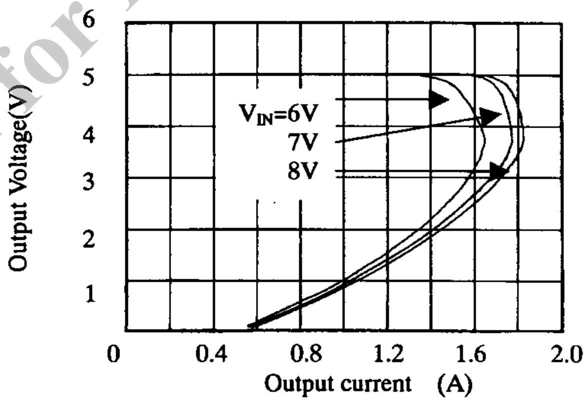
(4) Load regulation



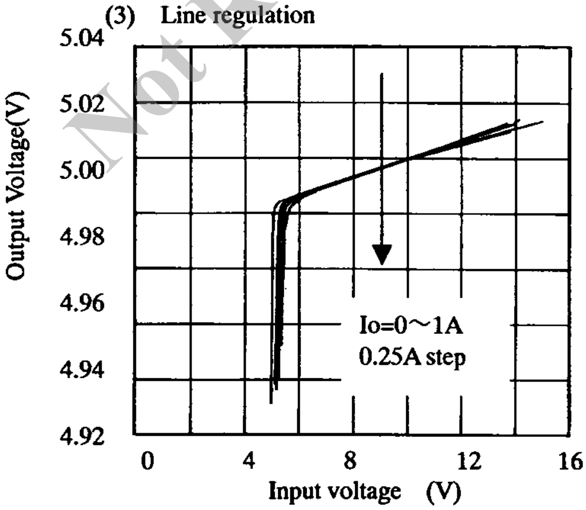
(2) Input voltage vs. Output voltage



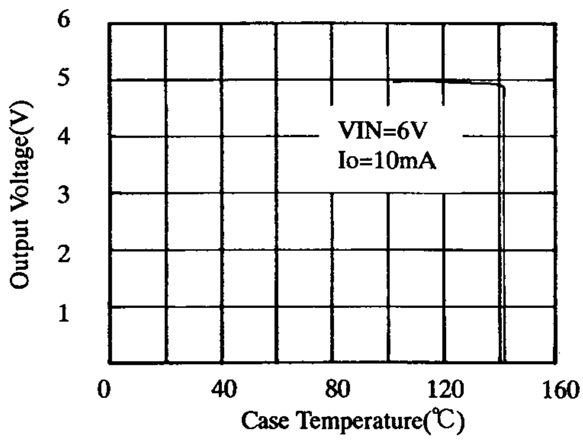
(5) Over current protection



(3) Line regulation

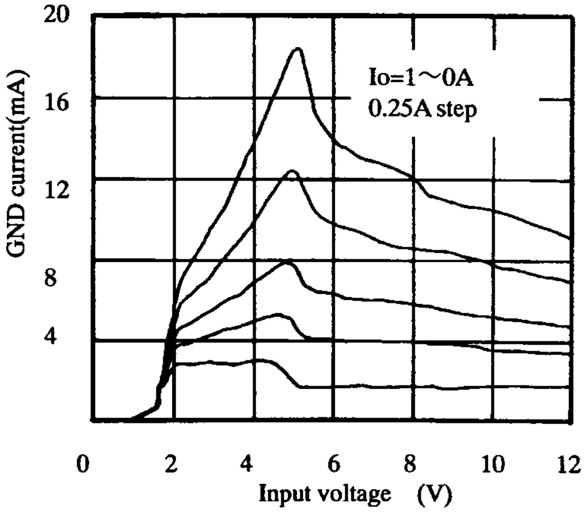


(6) Thermal protection

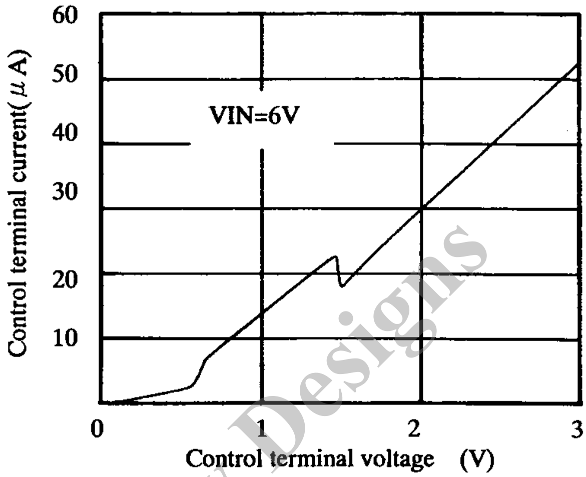


10.SI-3050LSA 代表特性例(2)　（Ta=25℃）
SI-3050LSA　Typical characteristics (2) (Ta=25℃)

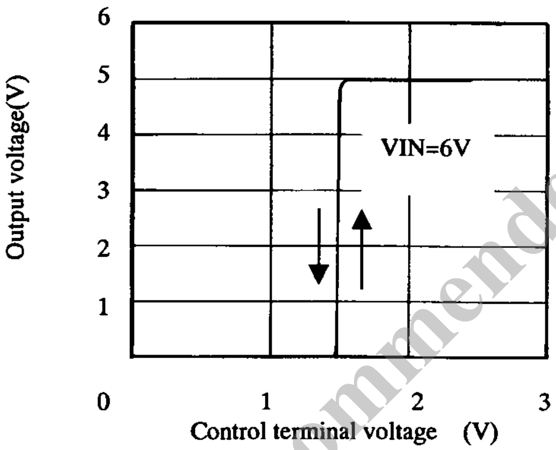
(7) Input voltage vs. GND current



(9) Control terminal voltage vs. Control terminal current



(8) Control terminal voltage vs. Output voltage



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